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Strategic Environmental Research and Development Program

Improving Mission Readiness Through Environmental Research

NSWC
Naval Surface Warfare Center
INDIAN HEAD DIVISION

Model-Based Green Gun Propellant Formulations Demilitarization Module

Cost and Environmental Analysis

Prepared For the

Indian Head Division,
Naval Surface Warfare Center
(Contract Number N00174-96-D-0005)

May 1999

BOOZ·ALLEN & HAMILTON INC.
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1 INTRODUCTION

The environmentally sound demilitarization of energetic materials is a significant issue for the energetic materials community. The Senate Armed Services' Committee has described munitions storage depots in the United States as being at their maximum storage capacity, without room for new munitions until such time as the existing munitions stockpile is reduced.[1] The Committee's Report for the FY99 Defense Authorization Bill estimates that there are over 400,000 tons of obsolete, unserviceable or unusable conventional munitions awaiting demilitarization, with that total expected to grow by an additional 400,000 tons by the end of Fiscal Year 1999. The Joint Demilitarization Technology Program estimates that the current demilitarization stockpile requiring resource recovery or disposition costs more than $11 million per year to store.[2] The recent Strategic Environmental Research and Development Program (SERDP) Energetic Materials Environmental Study reports that in the coming years, millions of pounds of gun propellant, with a typical shelf life in excess of 40 years, will be produced by DoD.[3] Ensuring a safe and effective means of demilitarizing and disposing of these munitions has become a serious concern to regulators and a costly burden on the DoD logistics system.

At the same time that demilitarization inventories are increasing, the use of destructive methods to reduce the inventory is coming under more intense regulatory scrutiny. As compliance with environmental regulations further restricts traditional methods of munitions demilitarization and disposal, efforts to develop "environmentally sound" energetic materials that are more responsive to resource recovery are more important. Energetic materials with components that are capable of being easily recovered make sense environmentally for several reasons. Not only will they reduce the overall demilitarization waste stream that requires treatment and disposal, but they also have the potential to reduce life cycle environmental costs by displacing virgin energetic materials and the environmental impacts associated with their production.

Model-based technology has the potential to reduce substantially the amount of hazardous waste generated across the life cycle of new gun propellants. Computer models should be able to generate much of the quantitative and qualitative data required for formulating, processing, and qualifying new propellants, and capture the costs and potential environmental effects associated with demilitarization activities. The Indian Head Division Naval Surface Warfare Center (IHDIV, NSWC), under the sponsorship of SERDP, is leading an effort to use computer models as an aid in the development of new gun propellant formulations. The objective of this initiative is to construct an integrated modeling architecture that can be used to:

- Streamline the development of new propellant formulations;
- Allow tailoring of compositions to meet specific performance/processing parameters;
- Reduce the amount of waste generated during product development; and

1 Senate Armed Services Committee Report for FY99 Defense Authorization Bill.
2 DoD Joint Demilitarization Technology Program, Section 1-1, February 1998
3 SERDP Energetic Materials Environmental Study, Section 1.1.4, Steve Thompson, NSWC Indian Head Division, March 1999

- Estimate the costs and environmental effects associated with future demilitarization activities.

While the modification of binders, plasticizers, and other additives provides opportunities to increase production efficiency and to reduce the production impact of energetic materials, it is during demilitarization that the effects of such modifications provide the single greatest opportunity for significantly reducing the life cycle environmental impacts of energetic materials.[4,5]

1.1 PURPOSE

The purpose of the *Model-Based Green Gun Propellant Formulations – Demilitarization Module Cost and Environmental Analysis* (conducted by Booz·Allen & Hamilton Inc. (Booz·Allen)) is to conduct a side-by-side cost analysis and environmental impact comparison for the demilitarization of three alternative gun propellant formulations:

- EX-99;
- An RDX/Thermoplastic Elastomer (TPE) formulation; and
- M30A1.

Open burning/open detonation (OB/OD) and other destructive demilitarization technologies result in no usable end-products, contribute to air, water, and soil pollution, and may ultimately incur additional costs associated with future site remediation. However, resource recovery technologies have a net positive impact on the environment by providing DoD with the ability to reclaim potentially valuable energetic material constituents. Once reclaimed, these materials may be recycled into end products that are useful to the Defense community or sold to the commercial sector. Additionally, these reclaimed materials also represent a potential cost avoidance, because they are not disposed as solid or hazardous wastes. Consistent with the current DoD emphasis on the reclamation and reprocessing of energetic materials for alternate uses, Booz·Allen has chosen to focus the analysis on current and emerging resource recovery and recycling (R3) technologies. The investigation and implementation of pollution prevention technologies like the ones discussed in this report are strongly encouraged by numerous Federal laws and regulations, Executive Orders, and DoD Directives, Regulations, and Instructions. The results of this analysis will serve as proof of concept that computer models can be used to capture and predict the economic and environmental costs associated with demilitarization activities, and will validate an important module in the developing Model-Based Green Gun Propellant Formulations architecture.

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4 *Clean Agile Alternative Binders, Additives and Plasticizers for Propellant and Explosive Formulations*, D. Mark Hoffman, et al, Lawrence Livermore National Laboratory, Life Cycles of Energetic Materials Meeting, Del Mar, CA, December 1994.

5 *Data Collection for Life Cycle Assessment Models, Part 1*, GBU-24B/B Penetrator Bomb, NSWC IHDIV Technical Report 1784, Kirk Newman, Richard Hardy, NSWC Indian Head Division, January 1995.

1.2 APPROACH TO COST ANALYSIS

Booz·Allen has utilized a five step approach to performing the *Model-Based Green Gun Propellant Cost and Environmental Analysis* (Figure 1).

STEP 1: The first step involves defining (1) the scope of the analysis (e.g., global parameters), (2) the analysis boundaries (e.g., the life cycle stages to be analyzed), (3) the processes or activities to be assessed and (4) process and organizational flows. This first step establishes the framework for the subsequent data collection and analysis activities.

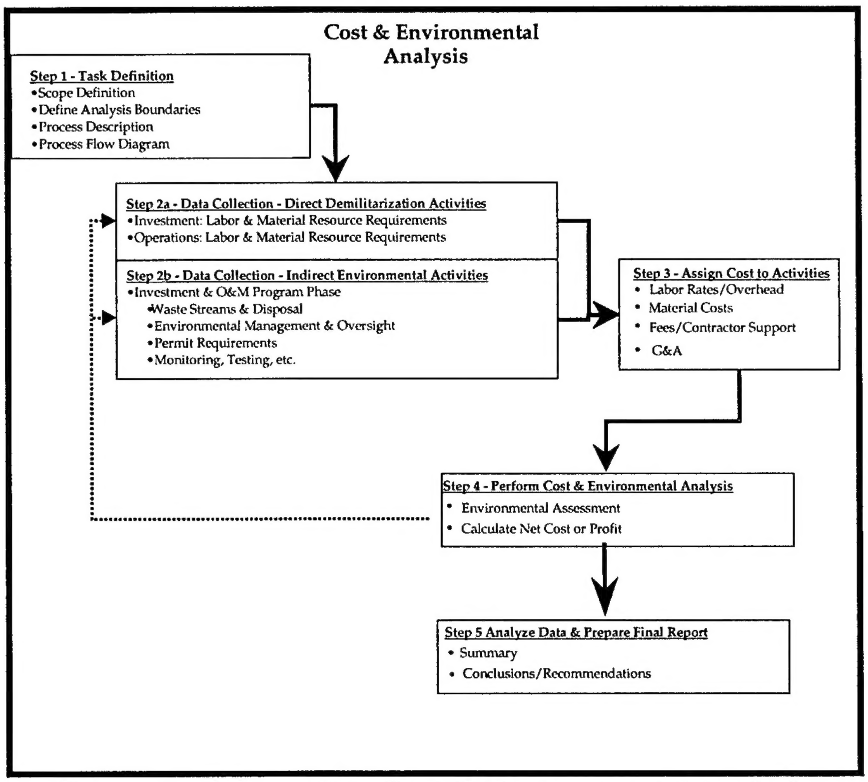

Figure 1 – Approach to Cost & Environmental Analysis

STEP 2: The second step involves collecting and quantifying program and cost data that accurately reflects the resources consumed during the production process, as defined by the scope.

- Program data includes general facility information, organizational structure, process information (e.g., flow charts, process descriptions) and environmental management information (e.g., regulations, procedures, oversight).
- Cost data focuses on capturing and quantifying the resources (e.g., labor, materials) consumed during the production process, including support activities (e.g., waste disposal). The resource consumption information and cost data are normalized into a standard unit measure (e.g., dollars/pound or hours/pound) for consistency and comparability.

STEP 3: The third step involves applying the cost data to the unit resources consumed during the process analyzed. The result is a time-phased cost estimate that will be used for cost and financial analysis and comparison.

STEP 4: The fourth step is to perform a cost analysis on the estimate results for each propellant formulation alternative.

STEP 5: The final step is to collect the results and generate a final report. The final report documents the scope, assumptions and constraints, results and recommendations.

1.3 APPROACH TO ENVIRONMENTAL ANALYSIS

In order to characterize the environmental, safety, and health (ESH) effects associated with the demilitarization of the alternative gun propellant formulations, Booz·Allen has utilized a three step approach.

STEP 1: The first step identifies and reviews applicable environmental regulations, directives, instructions, etc., that influence or impact demilitarization activities.

STEP 2: The second step evaluates the ESH effects of the individual chemical constituents of the alternative gun propellant formulations.

STEP 3: The third step attempts to identify and quantify waste streams associated with the alternative gun propellant formulations and R3 activities.

2 SCOPE

The scope of the *Model-Based Green Gun Propellant Formulations – Demilitarization Module Cost and Environmental Analysis* is to assess the financial and environmental impact to demilitarize 100,000 pounds of EX-99[6] propellant a year. Calculations are based on five scenarios each increasing by increments of 100,000 pounds in each scenario.

Inclusive within this analytical boundary are the costs and resources consumed that directly support the propellant demilitarization process.

This analysis is not a full life-cycle cost analysis because it does not evaluate capital investments, production and storage costs or other resource costs outside of the analysis's boundary. Operations, processes or activities outside the boundary include, (1) pre and post staging activities such as Shipping & Receiving, Inventory, and Quality Assurance and (2) the disposal of propellant charge hardware.

6 A variation of the M43 LOVA nitramine gun propellant.

3 DATA COLLECTION

Booz·Allen took a four-staged approach to data collection that included literature searches, review of technical reports and presentations, leveraging information gathered from existing programs, and conducting site visits.

1. General information regarding RDX reclamation and recovery of value-added products was obtained from literature searches of the Defense Ammunition Center and the Joint Demilitarization Technology Program.
2. Technical reports and presentations were reviewed, including:
    - *Demilitarization of Energetic Materials and Recovery of Value-Added Products* TPL, Inc., February 1998.
    - *"A Swords to Plow-Shares" Demilitarization Approach*, ARCTECH, Inc.
    - NSWC-IH Technical Report, (IHTR) 2036, "Feasibility of Reclamation and Reuse of RDX for Joint Mine Countermeasure Programs."
3. Information obtained as part of the on-going Green Energetic Materials (GEM) Program was reviewed.
4. Site visit and personal conversations with ARCTECH, Inc.

4 EX-99 PROPELLANT

The EX-99 gun propellant alternative is a nitramine-based formulation containing approximately 76% RDX, 12% cellulose acetate butyrate (CAB) binder, 7.6% bis(2,2-dinitropropyl)acetal/formal (BDNPA/F) plasticizer, 4% nitrocellulose (NC), and 0.4% ethyl centralite (EC) stabilizer.

4.1 GENERAL ASSUMPTIONS

Much of the information used to characterize the demilitarization of EX-99 using mineral acid extraction is derived from NSWC-IH Technical Report, (IHTR) 2036, "Feasibility of Reclamation and Reuse of RDX for Joint Mine Countermeasure Programs."[7] This technical report discusses the feasibility of reclamation and recovery of RDX for joint mine countermeasures programs given the current high cost of obtaining RDX from U.S. Army Industrial Operations Command (IOC) Army Ammunition Plants (AAP). A cooperative leveraging agreement has been proposed between the Environmental Security Technology Certification Program (ESTCP), the NSWC Crane Division, and TPL, Inc., to further investigate the merits of mineral acid extraction techniques.

For purposes of this analysis, several general assumptions have been made. It is assumed that the process described in IHTR 2036 for the recovery of RDX from Composition A-3 and HMX from LX-14 is equally effective for recovering RDX from the EX99 gun propellant. It is assumed that operations will take place at an existing industrial location that currently has the

[7] *Feasibility of Reclamation and Reuse of RDX for Joint Mine Countermeasures*, IHTR 2036, Kirk Newman, et al, NSWC IH, 31 October 1997

required equipment (e.g., jacketed reaction vessels, blast containment structures). While IHTR 2036 notes that no estimate of process yield is provided, previous contact with the vendor during the GEM Program resulted in claims that the process results in a "near zero waste stream". As no further information was provided, for purposes of this analysis, it is assumed that the process is closed-loop in nature (thus does not generate a liquid or gaseous solvent waste stream), but does generate 5% of solid waste (or 0.05 lbs of waste per lb of product treated). It is also assumed that no secondary waste streams are generated from accessing the gun propellant because process operators are able to empty the propellant casing of its contents by simply pouring out the individual charges.

4.2 Process Description

The major steps of the demilitarization process include: (1) Digesting the gun propellant in nitric acid, (2) Filtering the insoluble binder materials, (3) Precipitating RDX out of the acid (4) Cleaning the recovered material, and (5) Possible recrystallization of the RDX.

STEP 1: The propellant granules are placed in a jacketed reactor vessel filled with nitric acid. Mechanical stirring and heating start the digestion process of the RDX component. It is assumed that the reactor vessel is outfitted with vapor recovery equipment to capture nitric acid fumes. The RDX fraction of the propellant is digested in the nitric acid, while the insoluble binder fraction remains suspended in the solution.

STEP 2: After digestion, the suspended binder material is physically separated from the nitric acid by filtration and collected.

STEP 3: Water in a volume equal to the volume of the nitric acid solution is added, causing the dissolved RDX to precipitate out.

STEP 4: The precipitated RDX is filtered out of the nitric acid/water solution, washed with water to achieve a neutral pH, and is directed to a drying area. The nitric acid wash is neutralized to a pH between 5 and 6 using ammonium hydroxide.

STEP 5: Recovered nitramine may require recrystallization in order to obtain particles of the desired size.

The process flow diagram (Figure 2) illustrates the direct activities and resources consumed.

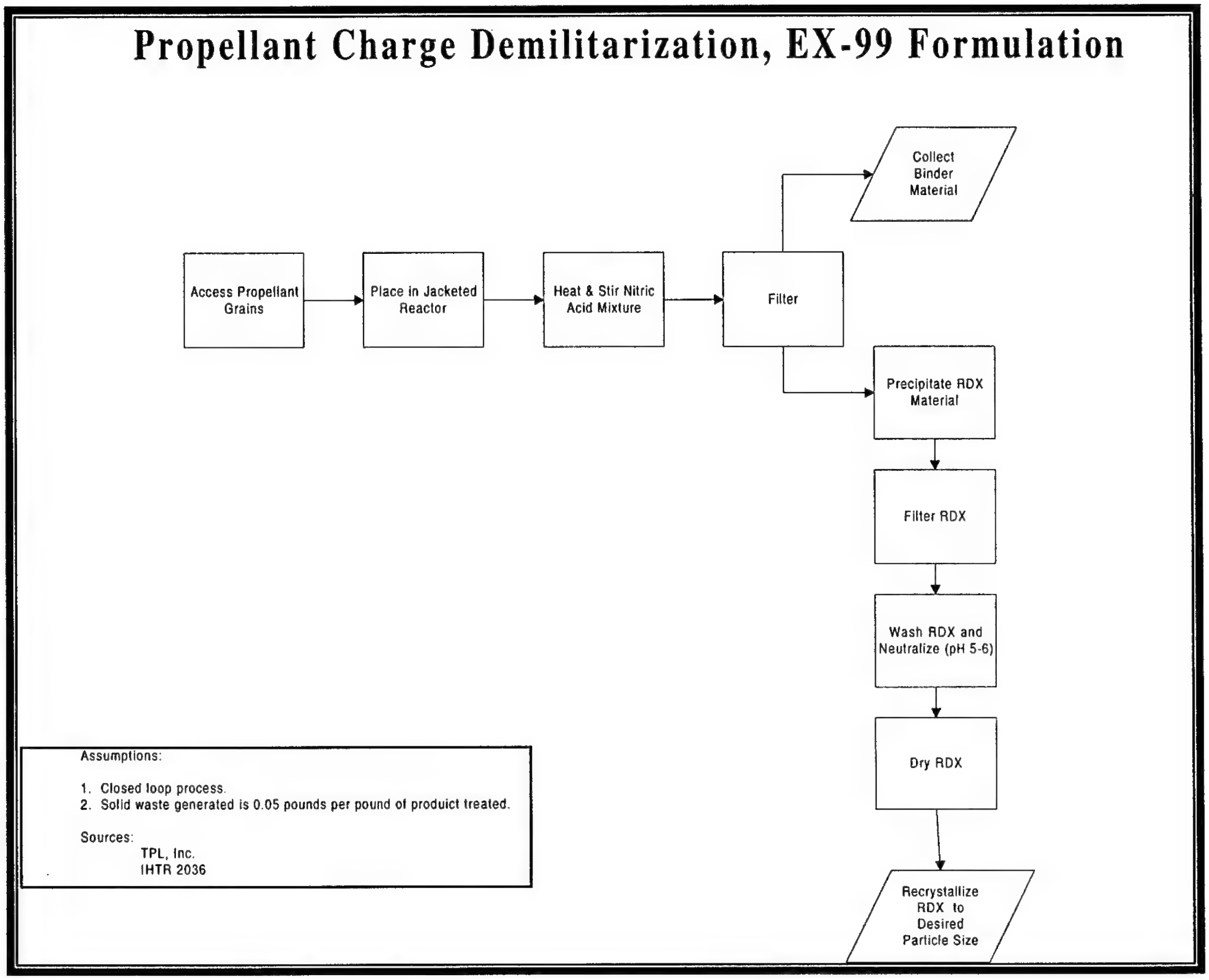

Figure 2: Propellant Charge Demilitarization, EX-99

4.3 EX-99 Cost Analysis

In *Demilitarization of Energetic Materials and Recovery of Value-Added Products,* costs are presented based on three levels of demilitarization. For the purposes of this analysis, the full-scale plant with a capacity of recovering 4,000 pounds of RDX per day was considered. The five scenarios presented are quantity variations of 100,000 pound increments, starting at 100,000 pounds.

The cost estimates are based on 2,000 hours in one year (10-hour shifts, 200 days per year). IHTR 2036 presents the labor and material charges together at \$2.50 per pound.[8] An additional cost for recrystallization and fluid energy milling of \$6.00 per pound is added to these direct production costs. This subtotal cost of \$8.50 per pound is adjusted from fiscal year 1997 to 1999 dollars, totaling \$8.53 per pound for the cost of demilitarization.

8 *Feasibility of Reclamation and Reuse of RDX for Joint Mine Countermeasures*, IHTR 2036, Kirk Newman, et al, NSWC IH, 31 October 1997

The baseline cost of virgin RDX material used for this cost and environmental analysis was $13.06 per pound. It is assumed that the market for reclaimed RDX will support 50% of the baseline RDX cost. Thus, the resale of RDX results in $6.53, The total net cost of the reclamation of RDX is $2.00 per pound (Table 1).

Pounds of Energetic per Year	100,000	200,000	300,000	400,000	500,000
Labor & Material ($/lb)	**2.50**	**2.50**	**2.50**	**2.50**	**2.50**
Additional Cost of Recrystallation / Fluid Energy Milling ($/lb)	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**
Subtotal Direct Production	**8.50**	**8.50**	**8.50**	**8.50**	**8.50**
Adjust to Constant FY 99 Dollars	**8.53**	**8.53**	**8.53**	**8.53**	**8.53**
Total Cost for Demilitarization	**8.53**	**8.53**	**8.53**	**8.53**	**8.53**
Cost per Pound	*$ 8.53*	*$ 8.53*	*$ 8.53*	*$ 8.53*	*$ 8.53*
Resale of RDX**	$ 6.53	$ 6.53	$ 6.53	$ 6.53	$ 6.53
Total (Cost) Profit per pound	**$ (2.00)**	**$ (2.00)**	**$ (2.00)**	**$ (2.00)**	**$ (2.00)**

** Market Supports 50% of Baseline RDX Cost

Table 1: Demilitarization Costs for EX-99 Propellant

5 TPE/RDX PROPELLANT

The TPE-based gun propellant alternative is a formulation containing approximately 76% RDX, 23.5% TPE binder, and 0.5% graphite.

The use of TPE binders in energetic materials is desirable because their solidification process is based on a reversible, physical change rather than irreversible chemical change. When heated above the softening temperature of the hard block, a TPE-based compound can be cast or extruded as a viscous liquid.[9] Assuming that necessary equipment modifications have been implemented, at the end of an energetic material's life cycle it should be possible to remove the material simply by heating it above the transition temperature of the hard block and pouring it out. Upon removal, the material can be analyzed to determine if it is still within specification. If the material remains within specification, it can be reused for military purposes. If it does not remain within specification, it can be easily reformulated to meet specifications, or sold for commercial use. Studies currently being conducted under the GEM Program indicate that while a heat-based demilitarization process for TPEs is likely in the near future, the technology is not sufficiently mature for actual implementation. The recovery of both the RDX and the TPE binder components of the gun propellant are currently achievable, however, through the use of a closed-loop, solvent extraction procedure that employs methanol as a solvent.[10]

5.1 GENERAL ASSUMPTIONS

For purposes of this analysis, several general assumptions have been made. It is assumed that operations will take place at an existing industrial location that currently has the required

[9] *Clean Agile Alternative Binders, Additives and Plasticizers for Propellant and Explosive Formulations,* D. Mark Hoffman, et al, Lawrence Livermore National Laboratory, Life Cycles of Energetic Materials Meeting, Del Mar, CA, December 1994

[10] GEM Technical Integrated Product Team Meeting, 28-29 January 1999

equipment (e.g., jacketed reaction vessels, blast containment structures) It is assumed that the closed-loop solvent extraction process identified by the GEM Program is used to extract the recoverable components of the gun propellant, a commercial market exists for the recoverable RDX component of the gun propellant, and that a DoD market exists for recoverable TPE.[11] It is also assumed that no secondary waste streams will be generated because process operators will be able to empty the propellant casing of its contents by simply pouring out the individual charges.

5.2 PROCESS DESCRIPTIONS

The major steps of the demilitarization process include: (1) Grinding the propellant charge into a fine mass, (2) Digesting the energetic materials in methanol, (3) Filtering the methanol to extract the TPE binder, (4) RDX Recrystallization, and (5) TPE recovery.

STEP 1: The individual propellant charges are cryogenically ground into a fine mass using a Wiley Mill and by passing it through a 20 mesh sieve. The resulting mass consists of propellant granules approximately 850μ in size.

STEP 2: The propellant granules are placed in a jacketed reaction vessel containing methanol, heated to 50°–55° C, and stirred for up to 48 hours. The soluble RDX fraction of the propellant material is digested in the methanol, while the insoluble TPE fraction remains suspended in the solution. It is estimated that approximately 30 pounds of methanol is needed for every one pound of propellant treated.

STEP 3: The suspended TPE is physically separated from the methanol by filtration and collected as a wet mass. The methanol is directed to the RDX recrystallization area.

STEP 4: RDX is recovered from the methanol by evaporation. The evaporated methanol is captured, condensed, and returned to the extraction loop for use in continued processing. Negligible particle size attrition has been observed in the recovered RDX. It is estimated that 99% of the original RDX content of the propellant is recoverable with negligible particle size attrition.

STEP 5: The previously collected TPE mass is rinsed with additional methanol to remove remaining RDX contamination. The rinse is returned to the extraction loop for processing until it no longer contains RDX. The purified TPE mass is vacuum dried until it consists of finely divided TPE flakes. It is estimated that approximately 99% of the TPE is recoverable.

The process flow diagrams (Figure 3) illustrate the direct activities and resources consumed.

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11 Green Enegetic Materials, *Informal Commercial Market Survey*, Phase I Environmental Report, May 1998

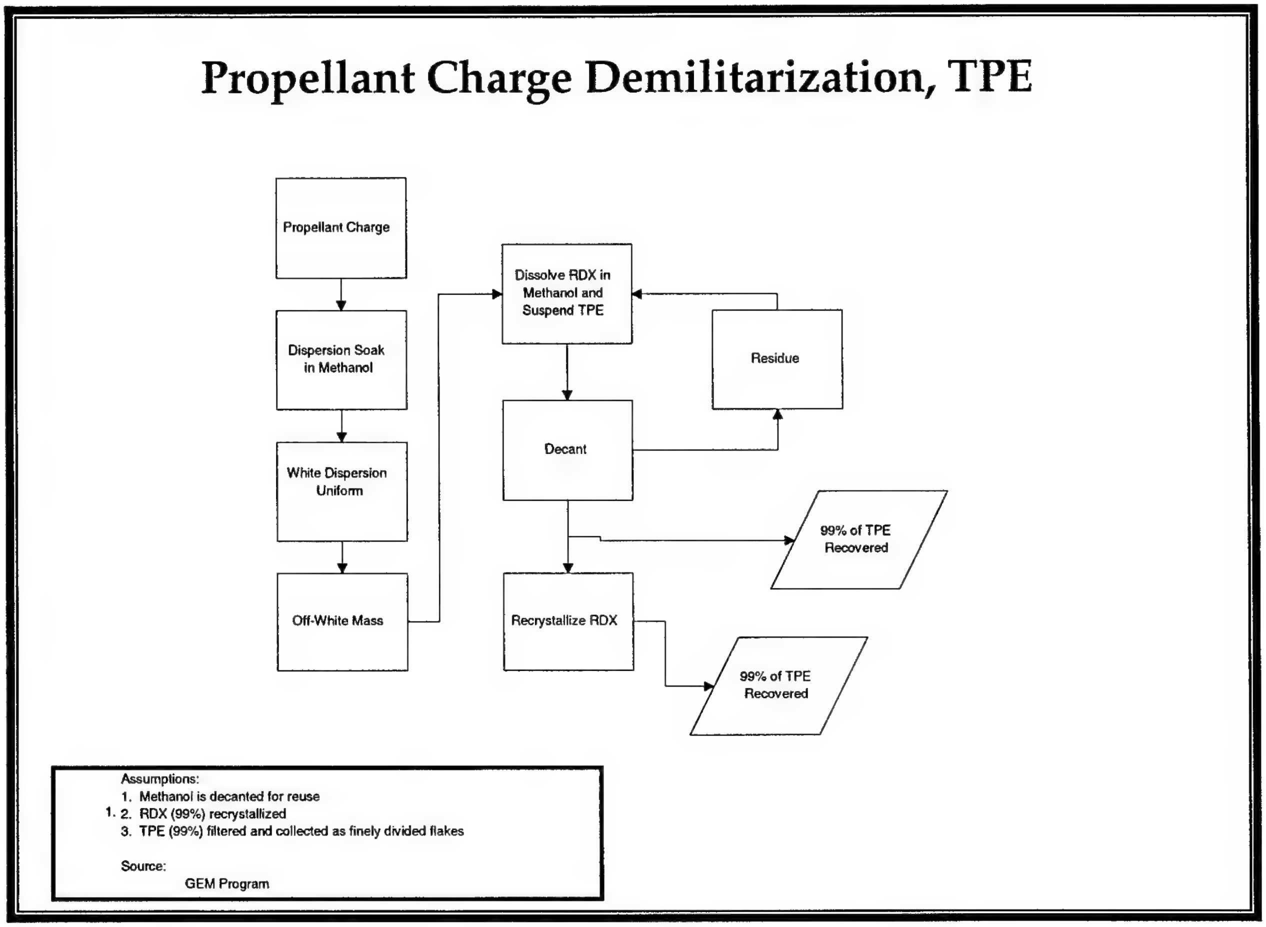

Figure 3: Propellant Charge Demilitarization, TPE

It is estimated that 99% of both the RDX and TPE constituents of the propellant charge are recoverable by this demilitarization method. Additionally, as the system is closed loop in nature, neither solvent nor liquid wastes are expected. Total solid waste is estimated at 1%, or approximately 0.01 lb/lb demilitarized.

5.3 TPE COST ANALYSIS

The costs for demilitarizing TPE propellants are obtained from subject matter experts within the industry. The five scenarios presented are quantity variations of 100,000 pound increments, starting at 100,000 pounds. The labor and material costs for the demilitarization process of TPE propellants is presented in Tables 2 and 3. The totals for both labor and material costs include a 12% general and administrative (G&A) cost.[12]

[12] OMB Circular A-76

LABOR

The labor costs are based on labor hours (i.e., hours per year) multiplied by a labor rate. The labor rate used here is $65 per hour.[13] Two full-time employees (FTE) are required for this process and have 1,776 effective hours per year per batch for this process. The cost per pound for the personnel is presented below in Table 2.

Category	FTEs	Effective Hours/Year per Batch per FTE	Total Hours/Year	Cost per Year
Operations Staff	1.0	1,776	1,776	$ 115,440
Operations Staff	1.0	1,776	1,776	$ 115,440
Subtotal Labor Cost:	**2.0**		**3,552.0**	**$ 230,880**
G&A				**$ 27,706**
Total Labor Cost				**$ 258,586**
			Hours/Pound	**Labor Cost/Pound**
			$ 0.04	**$ 2.59**

Table 2: TPE Labor Costs

MATERIAL

The materials used in the demilitarization process are methanol and liquid nitrogen. The cost for liquid nitrogen is not captured due to the insignificant amounts used in the process. Methanol costs per pound is $32.28 and the calculations are presented in Table 3.

	Annual Requirements (pounds)	lbs / lb of Energetic	Cost/Pound	Cost/Pound of Energetic
Methanol:		34.81	$ 0.83	$ 28.82
Liquid Nitrogen:	100,000	0.0020		$ -
Subtotal:	100,000			$ 28.82
G&A				**$ 3.46**
Total Material Cost				**$ 32.28**

Table 3: TPE Material Costs

As shown in Table 4, the total cost for demilitarization of TPE propellant ranges from $34.87 to $32.80, depending on the quantity. The baseline cost of RDX used for this cost and environmental analysis was $13.06 per pound. It is assumed that the market for reclaimed RDX will support 50% of the baseline virgin RDX cost. Thus, the resale of RDX results in $6.53 per pound. The net total cost of the reclamation of RDX ranges from $28.34 to $26.27 per pound (Table 4).

[13] OMB Circular A-76

Pounds of Energetic per Year			100,000		200,000		300,000		400,000		500,000
Direct Labor ($/lb)		**$**	**2.59**	**$**	**1.29**	**$**	**0.86**	**$**	**0.65**	**$**	**0.52**
Direct Material		$	32.28	$	32.28	$	32.28	$	32.28	$	32.28
Subtotal Direct Production		**$**	**34.87**	**$**	**33.57**	**$**	**33.14**	**$**	**32.93**	**$**	**32.80**
Cost per Pound		*$*	*34.87*	*$*	*33.57*	*$*	*33.14*	*$*	*32.93*	*$*	*32.80*
Resale of RDX**		$	6.53	$	6.53	$	6.53	$	6.53	$	6.53
Total (Cost) Profit per pound		**$**	**(28.34)**	**$**	**(27.04)**	**$**	**(26.61)**	**$**	**(26.40)**	**$**	**(26.27)**

** Market supports 50% of Baseline RDX Cost

Table 4: Demilitarization Costs for TPE Propellant

6 M30A1 PROPELLANT

The M30A1 gun propellant is a triple-base formulation that contains approximately 27.96% nitrocellulose (NC), 22.47% nitroglycerin (NG), 46.92% nitroguanidine (NQ), 1.5% ethyl centralite (EC) stabilizer, 1.0% potassium sulfate, and 0.15% graphite.

ARCTECH, Inc., was awarded a contract by the U.S. Army IOC as part of the Joint Demilitarization Testing (JDT) Program to conduct validation and demonstration tests of its patented ACTODEMIL™ technology. Unlike the previously discussed technologies, energetic material recovery is not the goal of the ACTODEMIL™ process. The technology is somewhat unique as it is capable of chemically converting propellants of all types (e.g., single-, double-, or triple-base, nitramine) into salable fertilizer. The process has been successfully demonstrated at a 500 gallon scale at the Hawthorne Army Depot, and has reportedly treated up to 2000 lbs during a single run.[14] The process and estimated waste streams are briefly described below.

6.1 GENERAL ASSUMPTIONS

For purposes of this analysis, several general assumptions have been made. It is assumed that operations will take place at an existing industrial location that currently has the required equipment (e.g., jacketed reaction vessels, blast containment structures). It is also assumed that the process is closed-loop in nature, and that any nitrogen-bearing gas streams that may result from the denitrification of the gun propellant are captured and reused in the process.

6.2 PROCESS DESCRIPTIONS: M30A1 ALTERNATIVE

Information used to characterize the ACTODEMIL™ process for the demilitarization of energetic materials was obtained from U.S. Patent #5,538,530, Heaton, et al, 23 July 1996. The demilitarization process is a one-step procedure that denitrifies explosives and propellants while concurrently modifying the carbonaceous materials into humic acid that is suitable for plant fertilizer applications. The process is described below.

STEP 1: ACTOSOL® is mixed with an aqueous base solution (e.g., potassium hydroxide) at room temperature. Typically, energetic material concentration in the solution is limited to 20% for processing and safety considerations. In the case of triple

[14] Harley Heaton, ARCTECH Inc., April 1999

base propellants such as M30A1, nitrate and nitrite ions and ammonia are formed. The humate extract serves to fix the free nitrogen, preventing its loss as ammonia or NOx gases. The carbonaceous material remaining from the process is rendered permanently non-reactive as defined by the Resource Conservation and Recovery Act (RCRA), and is taken up in the humic acid matrix. After denitrification is complete, the product, generally used as an aqueous solution, is available for immediate use.

STEP 2: If so desired, the product can also be reformulated with additional plant nutrients, and neutralized through the addition of conventional acid (e.g., phosphoric, acetic, hydrochloric) to a pH between 5-10, preferably between 7-9.5 to achieve desired fertilizer properties. The solution can also be formulated as a dried/granulated and/or slow release product. The addition of micronutrients (e.g., water-soluble salts of iron, boron, manganese, magnesium, copper, zinc, and molybdenum) can improve the yield of agricultural and horticultural crops.

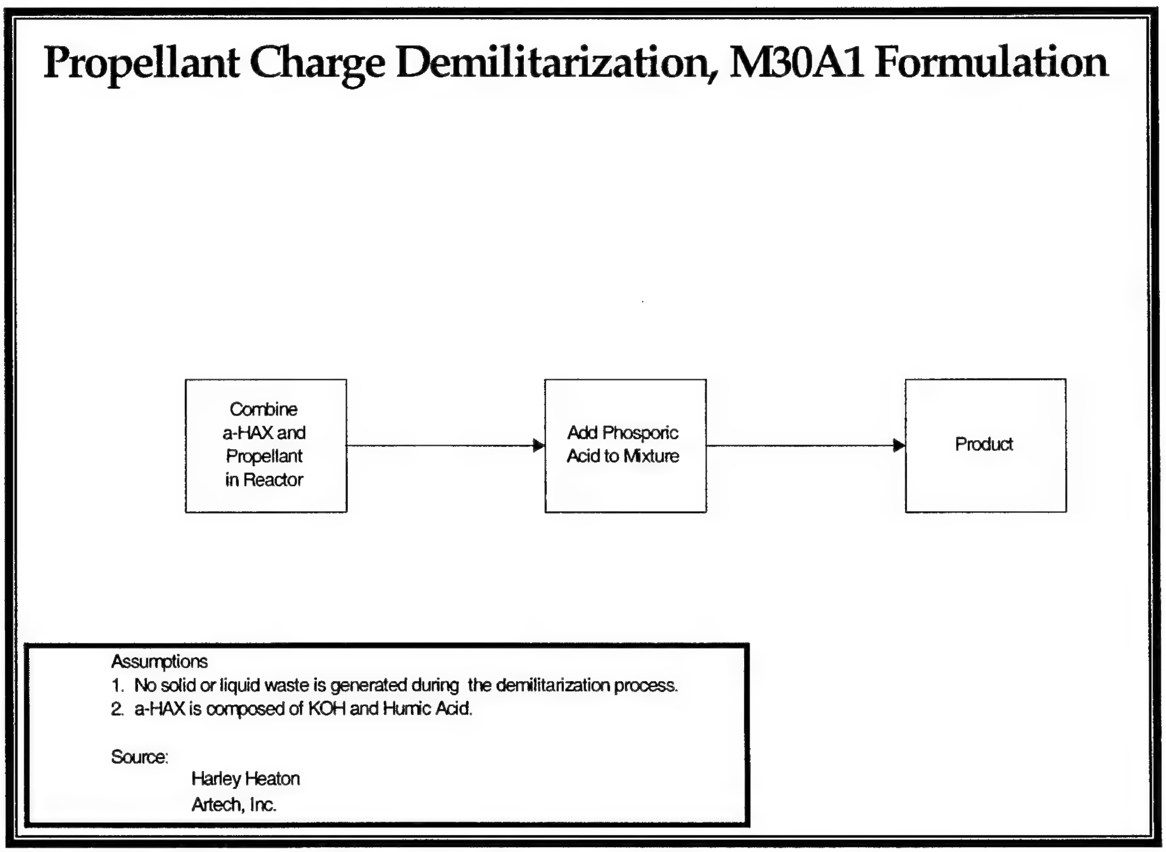

Figure 4: Propellant Charge Demilitarization, M30A1

6.3 M30A1 Cost Analysis

The costs for demilitarizing M30A1 propellants are obtained from Arctech, Inc. The five scenarios presented are quantity variations of 100,000 pound increments, starting at 100,000 pounds . The labor and material costs for the demilitarization process of M30A1 propellants are

presented in Table 5. The totals for both labor and material costs include a 12% G&A cost. The calculations are based on a quantity of 1,000,000 pounds of energetic per year.

LABOR

The labor costs are based on two full-time employees (FTE) at $40,000 per year each on a half time basis are required for this process. Calculations are based on a 1,000,000 pounds of energetic ($40,000/1,000,000 pounds). The start up and shut down phase of the process is usually 1-2 hours, and accounted for by using a labor multiplier. For the lower quantities of energetic, a multiplier was applied to compensate the proportional labor required for the start up and shut down phase. For quantities of 100,000 pounds, 200,000 pounds and 300,000 pounds of energetic, a multiplier of 1.7,1.2, and 1.1 are used, respectively. The labor costs per pound of energetic for each quantity scenario are provided in Table 6.

MATERIAL

The materials used in the demilitarization process are a-HAX (a mixture of KOH and Humic Acid), KOH, and H3PO4, and Antifoam. Costs for each ingredient on a per pound of energetic basis is provided in Table 5.

Material	Cost per Pound of Propellant Basis	
a-Hax	$	0.09
KOH	$	0.35
H3PO4	$	0.09
Antifoam	$	0.01

Table 5: Material Costs for M30A1 Propellant

The material costs remain constant for each scenario at 0.53 per pound of energetic. As shown in Table 6, the total cost per pound of demilitarization ranges from $0.67 to $0.64 and this includes the 12% G&A costs. The Program Income of $1.13 is from the sale of the "product" that is created from the demilitarization of the propellant. The total profit per pound of energetic ranges from $0.46 to $0.49.

Pounds of Energetic per Year		100,000		200,000		300,000		400,000		500,000
Direct Labor ($/lb)	**$**	**0.07**	**$**	**0.05**	**$**	**0.04**	**$**	**0.04**	**$**	**0.04**
Direct Material ($/lb)	$	0.53	$	0.53	$	0.53	$	0.53	$	0.53
Subtotal Direct Production	**$**	**0.60**	**$**	**0.58**	**$**	**0.57**	**$**	**0.57**	**$**	**0.57**
G&A	**$**	**0.07**	**$**	**0.07**	**$**	**0.07**	**$**	**0.07**	**$**	**0.07**
Total Cost for Demilitarization	**$**	**0.67**	**$**	**0.65**	**$**	**0.64**	**$**	**0.64**	**$**	**0.64**
Cost per Pound	*$*	*0.67*	*$*	*0.65*	*$*	*0.64*	*$*	*0.64*	*$*	*0.64*
Program Income ($1.125/lb Propellant for "product")	$	1.13	$	1.13	$	1.13	$	1.13	$	1.13
Total (Cost) Profit per pound	**$**	**0.46**	**$**	**0.48**	**$**	**0.48**	**$**	**0.49**	**$**	**0.49**

Table 6: Demilitarization Costs for M30A1 Propellant

7 ENVIRONMENTAL ANALYSIS

7.1 ENVIRONMENTAL REQUIREMENTS

The recent trend of an increasing number of environmental, safety, and health initiatives originating from within and from outside of DoD is likely to continue for the near future. This trend will continue to put significant pressure upon the energetic materials community to reduce the amount of life cycle waste generated. The following regulatory information summarizes many of the compliance and pollution prevention requirements applicable to the demilitarization module of the Model Green Gun Propellant Formulations effort.[15]

7.1.1 EXECUTIVE ORDERS

Executive Order 12088 - ***Federal Compliance with Pollution Control Standards***

EO 12088 subjects Federal agencies to the same substantive, procedural, and other requirements that apply to private citizens and corporations; requires Federal agencies to develop and submit a compliance plan to regulators when notified of a violation; and requires Federal facilities located outside of the United States to comply with the environmental pollution control standards of general applicability in the host country or jurisdiction.

Executive Order 12856 - ***Federal Compliance with Community Right-to-Know Laws and Pollution Prevention Requirements***

EO 12856 directs Federal agencies to provide appropriate Emergency Planning and Community Right-to-Know Act (EPCRA) related information concerning the toxic chemicals, hazardous chemicals, and extremely hazardous substances that are stored and used at Federal facilities to emergency response officials. EO 12856 also directs the Federal government to demonstrate pollution prevention leadership by improving facility management, incorporating environmental principles in acquisition practices, establishing pollution prevention goals and plans, and developing innovative technologies. The major components of EO 12856 include:

- Reduction of total releases of toxic chemicals to the environment, and off-site transfers for treatment and disposal, by 50% from a 1994 baseline;
- Development and implementation of a pollution prevention strategy that includes a commitment to utilize pollution prevention through source reduction, where practicable, as the primary means of achieving and maintaining compliance with applicable Federal, State, and local environmental requirements;
- Establishment of a plan and goals for eliminating or reducing the unnecessary acquisition of products containing extremely hazardous substances or toxic chemicals, and the development and testing of innovative pollution prevention technologies at their facilities; and

[15] Environmental Regulations Impacting the Energetic Materials Community, Steve Thompson, NSWC Indian Head Division, March 1999

- Reporting of all routine or accidental releases to the air, water, and land, as well as transfers to off-site treatment facilities, of chemicals subject to EPCRA's Toxic Release Inventory (TRI) reporting requirements.

As the traditional demilitarization of energetic materials generates regulated air emissions, hazardous solid waste, and can contaminate surrounding soils or water bodies, these types of releases are required to be inventoried and reported to authorities under EPA's TRI program.

Executive Order 12873 - ***Federal Acquisition, Recycling, and Waste Prevention***

EO 12873 directs Federal agencies to implement acquisition programs aimed at encouraging new technologies and building markets for environmentally preferable and recycled products. Agencies are required to incorporate use of recovered materials, reuse of product, life cycle cost, recyclabiltiy, use of environmentally preferable products, waste prevention, and ultimate disposal in their acquisition planning. Toward this end, all agencies are directed to review and revise their specifications, product descriptions, and standards. This requirement is consistent with on-going efforts to develop more environmentally benign energetic materials, production techniques that recover and reuse processing fluids, and energetic materials that are capable of being recovered, recycled, and reused at the end of their useful life cycle. The requirement for requalification of energetic formulations made with recovered materials would appear to be somewhat of a road block to the goal of incorporating recovered materials and building markets for recycled products.

Executive Order 13101 – ***Greening the Government through Waste Prevention, Recycling, and Federal Acquisition***

EO 13101 is the latest Executive Order issued for the purpose of increasing Federal agency use of recycled products. Under EO 13101, agencies are required to comply with Executive Branch policies for the acquisition and use of environmentally preferable products and services, and implement cost-effective procurement preference programs favoring the purchase of these products and services. While the primary focus of Federal recycling efforts remains paper products due to the large volume of such products acquired and discarded each year, the EO serves to emphasize just how serious the Federal government is about the acquisition and use of environmentally preferable products, and highlights the importance of current energetic materials community initiatives into the recovery, recycling, and reuse of energetic materials.

7.1.2 DoD Requirements

DoD Directive 4210.15 - ***Hazardous Material Pollution Prevention***

DoD Directive (DODD) 4210.15 establishes DoD policies and procedures regarding hazardous material pollution prevention. Under DODD 4210.15, it is DoD policy that hazardous material be selected, used, and managed over its life cycle so that DoD incurs the lowest possible cost required to protect human health and the environment. Emphasis must be on less use of

hazardous materials in processes and products vice traditional end-of-pipe management of hazardous wastes.

DoD Instruction 4715.4 – *Pollution Prevention*

DoD Instruction (DoDI) 4715.4 reiterates that it is DoD policy to comply with applicable Federal, State, interstate, regional, and local environmental laws, regulations, and standards, and with relevant EOs. It establishes that DoD policy is to reduce the use of hazardous materials, the generation or release of pollutants, and the adverse effects on human health and the environment caused by DoD activities. These objectives are to be accomplished using a four phased environmental management approach that emphasizes pollution prevention as the first choice for achieving compliance with applicable environmental requirements and Executive Orders; requires reuse of pollutants that cannot be eliminated; calls for the treatment of pollutants that cannot be prevented or reused; and uses the disposal or release of pollutants into the environment as a last recourse. The Instruction also establishes that DoD policy is to: incorporate pollution prevention into all phases of a weapon systems' life cycle (including demilitarization); reduce life cycle costs of weapon systems by avoiding the use of hazardous materials; and to develop, demonstrate, and implement innovative pollution prevention technologies. This Instruction should be viewed by the energetics community as a clear indication of the direction in which DoD would like activities using energetic materials to move, to formulations, processes, and other technologies that are amenable to pollution prevention and material reuse, and away from end-of-pipe treatment of process related waste streams.

DoD Instruction 4715.6 – *Environmental Compliance*

DoD 4715.6 establishes that it is DoD policy to ensure that environmental programs achieve, maintain, and monitor compliance with all applicable EOs, and Federal, State, interstate, and local statutory and regulatory requirements. DoD policy is also to participate in the development of plans and programs for achieving, maintaining, and monitoring environmental quality (e.g., the development of watershed protection plans, air quality implementation plans, etc.). Pollution prevention is recognized as the preferred means for attaining compliance. If available, commercially proven technology is to be used to achieve, maintain, and monitor compliance. If such technology is unavailable, the development of innovative solutions for the prevention of pollution is to be used where economically advantageous and consistent with mission requirements.

DoD Directive 5000.1 - *Defense Acquisition*

DoD 5000.1 establishes broad program management principles that are to govern defense acquisition programs of all sizes. It identifies three primary policies and principles that are to govern all defense acquisition programs: - Translating Operational Needs into Stable, Affordable Programs; Acquiring Quality Products; and Organizing for Efficiency and Effectiveness. DoD policy is to prevent, mitigate, or remediate environmental damage caused by acquisition programs. The Directive requires that wherever feasible, DoD personnel are to use all forms of pollution prevention and source reduction in the design, manufacture, test, operation, and disposal of systems. It is also DoD policy to coordinate and cooperate on acquisition efforts using

management tools such as Integrated Product Teams (IPT) to ensure that a true life cycle perspective (e.g., design, manufacture, test, operation, and disposal) is considered in acquisition efforts.

DoD Regulation 5000.2-R - *Mandatory Procedures for Major Defense Acquisition Programs and Major Automated Information System Acquisition Programs*

DoD 5000.2-R identifies the policies and procedures governing Major Defense Acquisition Programs. It requires the initiation of a programmatic environmental safety and health evaluation (PESHE) at the earliest possible time to support program milestone decisions. A Major Defense Acquisition Program is defined as one that is estimated to require the eventual total expenditure for research, development, test, and evaluation of more than $355 million, or more than $2.135 billion in total acquisition costs. All programs are required to comply with applicable Federal, State, interstate, and international environmental laws and regulations, EOs, treaties, and agreements. The issuance of DoD 5000.2-R marks a significant change in the manner in which DoD does business in that it requires the full assessment and integration of environment, safety, and health (ESH) considerations into the acquisition process. A key element of 5000.2R is pollution prevention. All forms of pollution are required to be prevented or reduced at the source for all design, manufacture, testing, operation, maintenance, and disposal of weapon systems. Pollution that can not be prevented must be recycled in an environmentally safe manner if possible. Program managers are required to establish pollution prevention programs, and to identify impacts of new systems on the environment, actions needed to prevent or control the impacts, the types and amount of pollution that will be released to the environment, and other information needed to identify source reduction and recycling opportunities.

7.1.3 REGULATORY REQUIREMENTS

The National Environmental Policy Act
42 U.S.C. 4321 ET SEQ.

NEPA establishes national environmental policy and goals for the protection, maintenance, and enhancement of the environment. NEPA mandates that Federal agencies utilize a systematic, interdisciplinary approach in evaluating proposed actions for their potential impact on the human environment. The human environment is the natural and physical environment, and the relationship of people with that environment. Some actions have the potential to significantly impact the human environment, and must be analyzed and the results documented before a decision to proceed is made. For such actions, NEPA applies a three-tiered procedural review process that considers environmental, socioeconomic, and cultural/historical impacts of proposed Federal actions. Each tier has associated documentation requirements, the level of detail of which is dependent upon the action's potential impact on the natural environment.

**The Resource Conservation and Recovery Act
42 U.S.C. 6901-6992**

In 1976, the Solid Waste Disposal Act was amended by the Resource Conservation and Recovery Act (RCRA). Regulations at 40 CFR 260-299 address the management of hazardous waste (Subtitle C) and solid waste (Subtitle D) in the United States. To be regulated under RCRA, a waste must first be determined to be a solid waste. Solid waste means any garbage, refuse, or sludge from a waste treatment plant, water supply treatment plant or air pollution control facility, and other discarded material, including scrap or excess energetic material. Hazardous waste is considered to be a subset of solid waste. RCRA establishes as national policy that: the generation of hazardous waste should be reduced or eliminated as expeditiously as possible; land disposal should be the least favored method for managing hazardous wastes; and all waste generated must be handled so as to minimize the present and future threat to human health and the environment. Although some States adopt Federal standards verbatim, many exercise their right to regulate the management of hazardous wastes by applying additional control requirements and more stringent standards.

Regulations promulgated under RCRA establish a "cradle-to-grave" system for managing hazardous waste from the point of generation to the point of ultimate disposal. A solid waste is considered hazardous under RCRA if it is specifically listed by EPA at 40 CFR 261 Subpart D, or if it exhibits any of the four hazardous waste characteristics of being ignitable, corrosive, reactive, or toxic. 40 CFR 264 and 265 establish comprehensive regulations for facilities that treat, store, or dispose of hazardous waste, including demilitarization facilities. Examples of treatment include: neutralization of a hazardous waste; rendering a waste non-hazardous; rendering a waste less hazardous; recovering energy from a hazardous waste; or reducing the volume of a hazardous waste. Examples of TSD facilities regulated under RCRA include OB/OD units, surface impoundments, waste piles, land treatment units, landfills, incinerators, thermal treatment units, underground injection wells, and other miscellaneous units. . Regulators demand item-specific empirical data before granting or extending RCRA Subpart X permits that are necessary for OB/OD operations, and in order to use incineration or other forms of thermal treatment at demilitarization sites, operators are required to first conduct a detailed waste stream analysis in order to determine the characteristics of the material to be demilitarization.

40 CFR 268 prohibits the disposal of hazardous waste on land if the waste does not receive prior treatment. Under the so-called Land Disposal Restrictions (LDRs), wastes become restricted and therefore subject to the LDR program when they are prohibited from land disposal by either regulation or statute. Examples of hazardous waste subject to the LDRs include energetic materials, solvents, heavy metals, and acids. Such waste materials are subject to universal treatment standards for hazardous constituents prior to being allowed in a RCRA land disposal unit (landfill, land treatment unit, waste pile, or surface impoundment).

The Clean Air Act 42 U.S.C. 7401-7671

The Clean Air Act (CAA), as amended, is designed to protect and enhance the nation's air quality so as to promote the public health, welfare, and productive capacity of the population. In

order to attain the goals of the CAA, EPA has promulgated regulations at 40 CFR Parts 50-99 establishing minimum ambient air quality standards for the nation and describing programs that must be implemented in order to achieve the standards. The combustion of propellants, explosives, and pyrotechnics during conventional demilitarization processes results in the emission of hydrogen chloride, heavy metal species, and potentially regulated smokes and mists Provisions of particular importance to the Model-Based Green Gun Propellant Formulations effort are those that target the emission of hazardous air pollutants. Examples of National Emission Standards for Hazardous Air Pollutants (NESHAPs) that may be applicable to energetic material processes include those for Hazardous Waste Combustion (specifically calling out destruction of energetic materials), Rocket Engine Test Firing, Explosives Production, and Research and Development

Clean Water Act (or the Federal Water Pollution Control Act) 33 U.S.C. 1251-1376

The primary objective of the Federal Water Pollution Control Act (FWPCA), commonly referred to as the Clean Water Act (CWA), is to restore and maintain the chemical, physical, and biological integrity of the nation's surface waters. The CWA strives to eliminate the discharge of pollutants into the nation's surface waters, and achieve a level of water quality that provides for the protection and propagation of fish, shellfish, and wildlife, and for recreation in and on the water. To achieve these broad objectives, the CWA requires each State to establish water quality standards for its surface waters based on the total amount (or loading) of pollutants that a water body can absorb without deterioration of a designated use. The NPDES Program also applies to facilities with storm water discharges associated with industrial activity, from a large or medium municipal storm sewer system; or for discharges which EPA or the State determine contribute to a violation of a water quality standard, or is a significant contributor of pollutants to waters of the United States. The conventional demilitarization of energetic materials results in secondary contaminants that may impact water quality and are therefore subject to CWA provisions. Demilitarization activities are required to develop a stormwater management plan in order to prevent stormwater runoff from carrying explosive and chemical contaminants that may have accumulated at the site from being discharged directly to a receiving body of water.

The Emergency Planning and Community Right-to-Know Act 42 U.S.C. 11001-11050

The Superfund Amendments and Reauthorization Act (SARA) of 1986 created the Emergency Planning and Community Right-to-Know Act (EPCRA), sometimes referred to as SARA Title III. EPCRA (40 CFR 350-372) is intended to improve community access to information regarding chemical hazards and facilitate the development of chemical emergency response plans by State and local governments. It is important to note that EO 12856 mandates Federal agency compliance with the requirements of EPCRA. The Section 313 Toxic Chemical Release provisions require that facilities included in SIC codes 20 through 39, which have ten or more employees, and which manufacture, process, or use toxic chemicals in amounts greater than threshold quantities, to submit an annual toxic chemical release (e.g., a TRI) report. This report is commonly known as Form R. Form R covers releases, whether routine or accidental, of listed chemicals to the air, water, and land, as well as discharges to POTWs and transfers to off-site treatment facilities, and includes releases resulting from demilitarization activities. TRI

Form R information is compiled by EPA in a national database on an annual basis and is available for review by the general public.

In March 1998, DoD issued guidance on applying EPCRA to munitions in order to meet the compliance requirements of EO 12856. Under the guidance, DoD facilities are required to comply immediately with the requirement to inform State and local emergency planners about the presence of extremely hazardous substances (EHS.) Accordingly, munitions and munitions items containing EHSs must be included in facility calculations for threshold requirements and reported to emergency planners. In determining hazardous chemical threshold calculations and inventories, stored munitions end items (e.g., rockets, bombs, fuses, etc.) are considered exempt from threshold calculation requirements. Hazardous chemical components of munitions and munitions-related items stored in bulk are not considered ordnance or munitions end items, however, and are therefore subject to inventory requirements. The guidance has significant ramifications for reporting releases to the environment that are attributable to the demilitarization and disposal of energetic materials. Effective the CY99 reporting cycle, demilitarization activities such as disassembly, dismantling, recycling, recovery, reclamation, and reuse shall be subject to TRI reporting requirements for processing activities. For these activities, facilities are required to report on each toxic chemical that exceeds the 25,000 lb "processing" threshold. Treatment activities such as OB/OD, incineration, chemical neutralization, and other such methods that alter the chemical composition of the munitions are subject to TRI reporting requirements under the 10,000 lb "otherwise used" threshold, and apply whether the treated munitions exist on-site, or were brought for treatment from an off-site location.

The Safe Drinking Water Act 42 U.S.C. 300a - 300j

The goal of the Safe Drinking Water Act (SDWA), as amended in 1996, is to protect human health from contaminants in public drinking water systems. Public drinking water systems include systems that provide piped water for human consumption if the system has at least fifteen service connections or regularly serves at least 25 individuals. Public health is protected through the establishment of Primary and Secondary drinking water standards, an underground injection control program, protection of aquifers that are the sole source of drinking water, and a wellhead protection program. EPA has promulgated regulations at 40 CFR 141-149 that implement SDWA requirements and address the protection of groundwater sources. States with Federally-approved programs are authorized to implement the SDWA.

The SDWA also requires EPA to establish a list of contaminants which are not subject to any proposed or promulgated national primary drinking water regulation, that are known or anticipated to occur in public water systems, and which may require regulation under the SDWA. In response to the requirement, EPA published the first Drinking Water Contaminant Candidate List (CCL) in March 1998. Several of the CCL contaminants are associated with the energetics community including 2,4-dinitrotoluene, 2,6-dinitrotoluene, aluminum, perchlorate, RDX, and sulfate and may contaminate drinking water sources around demilitarization activities. EPA is required to make a decision on whether to regulate the first group of chemical contaminants on the CCL by August 2001. The issue of groundwater contamination from AP has quickly risen to the forefront as a regulatory issue that can significantly impact the energetic materials community. Regulatory actions from State regulators, the identification of perchlorate as a

possible endocrine disrupting chemical, and the requirement that EPA report to Congress by the year 2000 on an endocrine disrupter screening program suggest future regulatory actions by EPA. The potential that other chemicals used by the energetic materials community will also be identified as endocrine disrupters is a distinct possibility.

The Comprehensive Environmental Response, Compensation, and Liability Act 42 U.S.C. 9601-9657

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund (40 CFR 300-374) authorizes EPA to respond to releases, or threatened releases, of hazardous substances that may endanger public health, welfare, or the environment. CERCLA also enables EPA to force parties responsible for environmental contamination to clean it up or to reimburse the Superfund for response costs incurred by EPA. The Superfund Amendments and Reauthorization Act of 1986 (SARA) revised several sections of CERCLA, extended the taxing authority for Superfund, and created a free-standing law, SARA Title III, or EPCRA. Regulations implementing the emergency response provisions of CERCLA are found in the National Oil and Hazardous Substances Pollution Contingency Plan, commonly called the National Contingency Plan or NCP. The NCP is quite extensive and addresses notification procedures for releases of hazardous substances into the environment, preliminary assessments of sites where releases may have occurred, remedial investigations, feasibility studies, remedy selection, remedial designs, and remedial actions. The NCP also provides for the National Priorities List, a list of national priority sites throughout the country where releases have occurred and EPA has determined that remedial actions are necessary.

CERCLA requires that energetic materials facilities report any environmental release of a hazardous substance that exceeds the reportable threshold quantities established for that substance to the National Response Center. Any such report initiates a formal process for assessing, removing, or remediating affected areas at a significant cost in order to diminish the threat to human health and the environment. The demilitarization of energetic materials provides pathways for the potential contamination of soils, groundwater, and surface water. Although normally reused or disposed of by incineration, imperfect energetic material or spilled energetic material collected during housekeeping of production facilities can find its way outside of facilities, and get swept up in storm water. OB/OD areas may be contaminated with explosives and heavy metals from past demilitarization operations and require remediation, and the landfilling of incinerator ash may result in contamination of soil with heavy metals.

The Pollution Prevention Act of 1990 42 U.S.C. 13101-13109

The Federal Pollution Prevention Act of 1990 (PPA) formally established pollution prevention as a national objective. Under the PPA, pollution that can not be prevented should be recycled. Pollution that can not be prevented or recycled should be treated in an environmentally safe manner whenever feasible. Disposal or other release into the environment should be considered only as a last resort, and should be conducted in an environmentally safe manner.

The Pollution Prevention Act provides the impetus for the integration of pollution prevention initiatives in DoD environmental requirements. This regulatory driver has been at least partially responsible for a significant decrease in the use of volatile and halogenated solvents and other hazardous chemicals by the energetics community, and has been instrumental in the DoD development of innovative low solvent or solventless processing and production technologies that also lower the volume of scrap material requiring treatment prior to demilitarization and disposal. Advanced demilitarization technologies based on material recovery, recycle, and reuse instead of destruction will lower the energetic material community's waste stream at its most significant point, the point of ultimate disposal.

The Toxic Substances Control Act 42 U.S.C. 2601-2629

Regulations promulgated under the Toxic Substances Control Act (TSCA) created a regulatory framework with which to collect data on the many new chemicals being introduced each year in order to evaluate, assess, mitigate, and control risks which may be posed by their manufacture, processing, use, distribution in commerce, and disposal. TSCA standards may apply at any point during a chemical's life cycle, and impact environmental effects during demilitarization activities. Because of the R&D exemption, toxicological and environmental information about many of the new experimental energetic materials being investigated for future use is not readily available. The import of chemicals not produced or available in the United States for use in the production of energetic materials may trigger TSCA requirements so that the risks posed by their processing, use, distribution, and disposal can be evaluated for their effect on human health and the environment.

Federal Facilities Compliance Act 42 U.S.C. 6901

The primary purpose of the Federal Facility Compliance Act (FFCA) is to ensure that State environmental agencies and EPA have the ability to impose civil penalties and administrative fines on Federal facilities under RCRA for violations of Federal, State, and local solid and hazardous waste laws. Prior to passage of the FFCA, Federal facilities, although required to comply with RCRA, had been granted sovereign immunity from fines and penalties for certain violations. The FFCA brings the Federal government in line with the private sector as it allows Federal facilities to be placed under the same scrutiny as private or commercial entities for the purposes of environmental enforcement civil penalty actions. Section 104(1) requires that EPA conduct an annual inspection of every Federal facility that has a RCRA TSD permit. Authorized States are also given the right, but not the obligation, to inspect Federal facilities, either in conjunction with EPA, or independently. During the first visit of these annual inspections, regulators are specifically required to review and comment on the facility's groundwater protection program. Facilities which treat, store, or dispose of potentially significant quantities of hazardous waste (such as energetic material demilitarization facilities) have a greater possibility for non-compliance with environmental regulations and may be under closer scrutiny from state or local authorities than other facilities.

The Hazardous Materials Transportation Act 49 U.S.C. 1801, et seq.

The intent of the Department of Transportation (DOT) regulations governing the shipment of hazardous materials (40 CFR 171 -179) promulgated under the Hazardous Materials Transportation Act (HMTA) is to protect transportation personnel and equipment from materials with dangerous properties. The regulations also provide the means for rapid identification of hazardous materials when encountered by emergency response personnel during transportation mishaps. RCRA Subtitle C requirements for the transportation of hazardous wastes is a subset of the broader universe of DOT-regulated hazardous materials. Together, the DOT and RCRA programs provide a comprehensive framework of standards to promote the safe transportation of materials from the initial site of shipment to their final destination at a receiving facility, and ultimate point of disposal (e.g., a demilitarization facility). Personnel involved in transport must be properly trained, and the populace protected from the potential hazards associated with the transport of energetic materials. While DoD standards essentially mirror DOT standards, if questions exist as to which standards have primacy, both sets of standards should be referenced against each other in order to ensure the safe transport of hazardous substances.

Office of Pollution Prevention and Toxics 1999-2005 Strategic Agenda

The Office of Pollution Prevention and Toxics (OPPT) is the EPA Office that is responsible for the development of new national strategies for toxic substance control, the promotion of pollution prevention, the life cycle management of environmental issues, and advancing the public's right to know about chemical risks. As such, the direction of its future efforts is of significance to the energetic materials community as it may provide insight into the type of regulatory actions or initiatives that may be coming down the road. In August 1998, OPPT released its Draft Strategic Agenda for FY 1999-2005.

In a particularly revealing statement, OPPT notes that a trend likely to influence the manner in which the Office carries out its mission during coming years is a continuation of the recent EPA shift away from the use of "command and control" type regulatory programs to a greater reliance on alternative mechanisms such as negotiated settlements with industry and voluntary pollution prevention measures. OPPT has stated its intention to help significantly increase the introduction and use of safer or greener chemicals that are less toxic, result in lower exposure, and generate less (or less toxic) waste. It also intends to screen and review by 2005 all chemicals in commerce, with special emphasis being placed on chemicals identified by current initiatives as potential endocrine disruptors or PBTs, and to reduce by 25% (from a 1992 baseline) the quantity of toxic pollutants released, treated, disposed of, or combusted for energy recovery by no later than 2005. While current initiatives have identified only a handful of chemical substances for potential regulation, they are far from being complete. Given the tone of the Strategic Plan, it is apparent that current energetic materials community pollution prevention efforts that encompass the use of less hazardous solvents, new processing technologies, and innovative binder systems are certainly moving in the right direction and should likely be expanded to look more carefully into the elimination of other toxic and hazardous materials in new energetic formulations.

Endocrine Disruption

In recent years scientists worldwide have proposed that certain chemicals referred to as endocrine disruptors may be causing adverse health effects in humans and wildlife alike by upsetting the normal functioning of endocrine systems. These problems have been identified primarily in species exposed to organochlorine pesticides, PCBs, dioxins, and synthetic and plant-derived estrogens. The endocrine system plays a critical role in regulating normal growth, development, and reproduction by producing hormones and secreting them directly into the bloodstream. Some of the endocrine glands include the pituitary, thyroid, and adrenal glands, and the female ovaries and the male testes. DoD, through the Tri-Services Toxicology Consortium at Wright-Patterson AFB in Dayton, OH, is participating in Federal agency Endocrine Disruptors Research Initiatives studies. The following chemical substances familiar to the energetic materials community have already been identified as potential endocrine disrupting chemicals, and are the subject of further investigation to better characterize their health effects:

- Ammonium perchlorate;
- Trinitrobenzene;
- Heavy metals such as lead, cadmium, and zinc;
- Ammonium dinitramide;
- Phthalates; and
- Isocyanates.

As is evidenced by the energetic material constituents already identified as being potential endocrine disruptors, this initiative has the potential to significantly impact the production, use, and disposal of energetic materials. Workplace exposure during OB/OD and other disposal options may come under increased regulatory oversight in the future, and efforts to minimize the release of endocrine disruptors to the environment seem likely.

Persistent, Bioaccumulative Toxics

EPA's 1994 RCRA Waste Minimization National Plan (WMNP) laid the foundation for a new program intended to promote voluntary waste minimization efforts by industry with regard to the release of persistent, bioaccumulative, and toxic (PBT) pollutants. PBT pollutants are characterized by their persistence in the environment, by the fact that they are not easily metabolized and can accumulate in human or ecological food chains via consumption or uptake, and because they may be hazardous to human health or the environment. Once released into the environment, chemicals that exhibit some combination of PBT characteristics are capable of causing chronic, long-term effects in receptor organisms, even if released in small quantities.

On 9 November 1998, EPA published a draft list of 53 PBT chemicals and chemical categories that may be found in RCRA hazardous wastes in the Federal Register. The list contains several chemicals and chemical categories familiar to the energetic materials community. These chemicals are released during current destructive demilitarization activities. They include:

- 1,1,1-Trichloroethane;
- Cadmium;
- Chromium;
- Copper;
- Dibutyl phthalate;
- Hexachlorobenzene; and
- Lead.

The same general type of impacts to the energetic materials community as can be expected from endocrine disrupting chemicals can be expected for PBTs, only more pronounced. This would be because of the persistent and bioaccumulative nature of PBTs. Chemicals that are PBTs have already been banned from commerce under TSCA by EPA (e.g., PCBs), setting an important precedent for future regulation of other PCBs.

The composition of the alternative gun propellant formulations were evaluated to determine their potential ESH effects and to identify how they are regulated under major environmental laws. Literature reviews were conducted, Material Safety Data sheets (MSDS) for individual constituents obtained and analyzed, and Chemical Abstract Service numbers (CAS#s) identified. The CAS#s were used to search EPA regulatory databases to determine the regulations applicable to the individual energetic material constituents.

Appendix A summarizes information pertaining to the ESH effects of baseline and alternative energetic material formulations.

8 MARKET FOR RECLAIMED RDX

The conventional demilitarization of energetic materials by OB/OD and other forms of thermal treatment are undesirable for several reasons. Conventional demilitarization activities are strictly regulated, and result in pollution of air, ground, and water resources. In addition, because they are destructive in nature, these activities do not allow for the recovery and reuse of potentially valuable constituents.

The use of R3 technologies can offset demilitarization costs if commercial markets can exist for the by-products generated by such technologies. An informal survey of commercial markets with potential interest in the acquisition of recovered RDX or HMX was conducted under the GEM Program. Results of the survey indicated that several commercial organizations associated with the mining and oil exploration industries are not only interested in acquiring recovered DoD RDX, but are already doing so. It was anticipated that commercial interest would be contingent upon the recovered material meeting some industry-wide purity standard. Surprisingly, conversations with Mr. Tom Dowling of the Institute of Makers of Explosives (IME) indicated that industry-wide purity standards for energetic materials do not currently exist.[16] However, most respondents expressed a desire to perform internal laboratory analysis on recovered energetic materials prior to purchase. A brief summary of the results are presented in Appendix B.

16 Conversations with Mr. Tom Dowling, Jan./Feb. 1998

9 CONCLUSIONS

Using available technical information, *Model-Based Green Gun Propellant Formulations – Demilitarization Module Cost and Environmental Analysis* performed a cost analysis and environmental assessment for the R3 demilitarization of three alternative gun propellant formulations. The analysis was not intended to be a detailed economic assessment of R3 technologies that would lead to recommendations of one technology and gun propellant formulation being favored over the others.

The objective of this task was to develop and demonstrate a generic computer-based model that uses Activities-Based Costing (ABC) techniques to assess the environmental costs associated with the demilitarization of specific gun propellants. ABC was chosen because of its usefulness in identifying hidden resources, consumed assets, or cost objects that may have excessive environmental costs associated with them, and assigning overhead costs directly to activities and products or processes to which they apply. Unlike conventional cost management systems that focus on direct labor, the ABC concept identifies cost drivers that measure resources consumed by activities to produce cost objects.

Every effort was made to account for all significant cost factors in order to produce the most useful cost estimates for comparative analyses. As is the case with any other model, the outputs are only as useful as the accuracy of the data that are entered into the model. The results of the analysis for the three alternatives are summarized in Table 7.

There is a marginal profit in the Arctech process when converting energetic material to salable fertilizer. However, this analysis does not incorporate marketing and capital investment costs.

Pounds of Energetic per Year	100,000	200,000	300,000	400,000	500,000
Total (Cost) Profit per pound					
EX-99	**(2.00)**	**(2.00)**	**(2.00)**	**(2.00)**	**(2.00)**
TPE	**(28.34)**	**(27.04)**	**(26.61)**	**(26.40)**	**(26.27)**
Arctech	**0.46**	**0.48**	**0.48**	**0.49**	**0.49**

Table 7: Summary (Cost) Profit per Pound

The results of this analysis are proof of concept that computer models can be used to capture and predict the economic and environmental costs associated with demilitarization activities, and serve to validate an important module in the developing Model-Based Green Gun Propellant Formulations architecture.

Appendix A

Environmental Safety & Health
Impact of Individual Chemical Constituents

EX-99

EX-99 is composed of approximately 76% RDX, 12% cellulose acetate butyrate (CAB) binder, 7.5% bis(2,2-dinitropropyl)acetal/formal (BDNPA/F) plasticizer, 4% nitrocellulose (NC), and 0.5% ethyl centralite (EC) stablizer. Demilitarization uses a nitric acid solution.

INGREDIENT	DESCRIPTION	ENVIRONMENT, SAFETY, AND HEALTH EFFECTS	REGULATION
RDX (CAS# 121-82-4)	RDX is the largest quantifiable ingredient of the propelling charge. RDX is an odorless, white-to-gray crystalline solid that is insoluble in water. It represents a moderate reactive hazard, and becomes unstable and may detonate with exposure to extreme heat, impact, or electrostatic discharge.	Upon decomposition, RDX produces hazardous NO_x fumes. Inhalation of RDX particulate matter is considered a chronic health hazard.	RDX is a reactive waste under RCRA and is on the SARA Title III Section 110 priority list of CERCLA hazardous substances. It has also recently been added to the Candidate List of Contaminants by the National Drinking Water Advisory Council
Cellulose Acetate Butyrate (CAB) (CAS# 9004-36-8)	Cellulose acetate butyrate is a white fluffy powder and/or chunks, that is stable under normal temperature and pressure.	Upon decomposition, CAB produces hazardous carbon monoxide, irritating and toxic fumes and gases, and carbon dioxide. CAB is incompatible with strong oxidizing agents and strong bases. Health and Safety precautionary equipment that should be used includes protective gloves, clothing, safety glasses, chemical goggles, and a NIOSH/MSHA-approved full face piece airline respirator in the positive pressure mode with emergency escape provisions. CAB must be stored in a cool, dry place, with the container closed when not in use. To keep airborne concentrations at a low level, it is suggested to use general or local exhaust ventilation.	N/A
Acetal/Formal Acetal (CAS#5108-69-0) / Formal (CAS#5917-61-3)	Bis-(2,2-dinitropropyl) acetal/formal is a straw colored to brown liquid, with an oily odor. Acetal/formal is stable in nature, but should be kept a safe distance form heat and flame to preserves its stability.	Acetal/formal represents a slight contact and fire hazard. Upon decomposition, acetal/formal produces hazardous COx and NOx. Health hazards include mild irritation to skin and mucous membranes. When working with acetal/formal in well ventilated areas no respirator is required. In poorly ventilated areas workers should wear a NIOSH/MSHA- approved organic vapor cartridge respirator; in more confined spaces workers should use a NIOSH/MSHA approved airline respirator SCBA.	N/A
Nitrocellulose (NC) (CAS# 09004-64-17-5)	Nitrocellulose is a white fibrous/cubed/granular solid. Sometimes called "gunpowder" or "guncotton", nitrocellulose is incompatible with strong oxidizing agents, strong acids, strong bases, and amines. It is more stable than black powder, and it produces a much greater	Nitrocellulose is extremely flammable and can be easily ignited by heat, sparks or flames. Workers should practice extreme care in handling nitrocellulose as it a chronic health hazard, and a moderate acute health and contact hazard. Inhalation or contact may irritate or burn skin and eyes; fire may produce irritating, corrosive and/or toxic gases; and vapors may cause dizziness or suffocation.. Conditions to avoid include heat, flame, other sources	

INGREDIENT	DESCRIPTION	ENVIRONMENT, SAFETY, AND HEALTH EFFECTS	REGULATION
	volume of hot gas.	of ignition, light, and shock. Toxic gases produced upon decomposition may include nitrogen oxides, hydrogen cyanide, carbon monoxide, and carbon dioxide. Facilities should use adequate general or local exhaust ventilation to keep vapor and mist levels as low as possible. Approved respiratory protection is required if airborne concentrations are expected to exceed acceptable limits. Safety glasses with side shields and rubber gloves are recommended as eye/skin protection for workers. Proper storage of nitrocellulose consists of a cool, dry, well-ventilated, flammable liquid storage area in light-resistant containers.	
Ethyl Centralite (CAS# 85-98-3)	Ethyl centralite is a white crystalline solid with a peppery odor used as a stabilizer for nitrocellulose-based smokeless powder and in rocket propellants. Ethyl centralite is not soluble in water and reacts violently when severely shocked or exposed to extreme temperatures. Fire or excessive heat may cause production of hazardous decomposition products.	Ethyl centralite presents a slight health, contact, and fire hazard. Upon decomposition, toxic NOx gases are produced. When working with ethyl centralite personnel should always wear gloves, mask, goggles and use a hood. In instances of skin contact, it is recommended that the affected area be washed liberally with soap and water. A local exhaust system is required when used.	N/A
Nitric Acid (CAS# 7697-37-2)	Nitric acid is a colorless to yellow liquid with a pungent odor. It is a strong oxidant, and reacts violently with combustible and reducing materials, bases, and organic chemicals such as acetone, acetic acid, etc.	Nitric acid is not combustible, but serves to enhance the combustion of other substances. It gives off irritating or toxic fumes, and inhalation may cause a burning sensation and labored breathing. Nitric acid cause painful burns upon contact with the skin. It is corrosive to the eyes, and will cause severe deep burns. The use of local ventilation, protective clothing, and face or eye protection in combination with breathing protection is recommended.	Nitric acid is an OSHA air contaminant, is regulated underCERCLA, the Department of Transportation, is a CAA Toxic, Explosive, or Flammable Substance, and is subject to TRI reporting requirements. In addition, it is listed as a California Air Toxics Hot Spots chemical. An OSHA PEL of 5 mg/m^3 is established for nitric acid.

TPE/RDX

The TPE/RDX alternative gun propellant is based upon a TPE binder system, and consists of approximately 76% RDX, 23.5% BAMO/AMMO, and 0.5% graphite. Demilitarization uses methanol.

INGREDIENT	DESCRIPTION	ENVIRONMENT, SAFETY, AND HEALTH EFFECTS	REGULATION
RDX (CAS# 121-82-4)	RDX is the largest quantifiable ingredient of the propelling charge. RDX is an odorless, white-to-gray crystalline solid that is insoluble in water. It represents a moderate reactive hazard, and becomes unstable and may detonate with exposure to extreme heat, impact, or electrostatic discharge.	Upon decomposition, RDX produces hazardous NO_x fumes. Inhalation of RDX particulate matter is considered a chronic health hazard.	RDX is a RCRA reactive D003 waste and is on the SARA Title III Section 110 priority list of CERCLA hazardous substances. It has recently been added to the Candidate List of Contaminants by the National Drinking Water Advisory Council
BAMO/AMMO	BAMO/AMMO (poly(bis(3,3-azidomethyloxetane) (3-azidomethyl-3-methyloxetane) is an energetic oxetane-based (AB)n block copolymer. BAMO/AMMO is an odorless, white solid that is insoluble in water. While not explosive, BAMO/AMMO will burn if flame is applied steadily. It is incompatible with amines, nitrogen tetroxide, acids, and heavy metals.	BAMO/AMMO contains aliphatic azides which will decompose vigorously at elevated temperatures. Undetermined organics are expected to result from the decomposition of BAMO/AMMO. If decomposition products are inhaled, contact a physician immediately. While respiratory protection is not required, mechanical ventilation and safety glasses with side shields are recommended, and impervious gloves should be worn when handling the material. Contaminated material should be picked up with non-metallic, non-sparking tools and discarded with caution.	Under TSCA regulations, BAMO/AMMO is for research and development use only. BAMO/AMMO is a RCRA reactive waste and regulated as an extremely hazardous substance under SARA Title III.
Graphite (CAS# 07782-42-5)	Graphite is a dark gray to black odorless powder which is combustible and should be kept away from heat, sparks, and flame in a tightly closed container. Contact with air and moisture should be avoided in storage areas. It is negligibly soluble in water..	Personal protective equipment for workers include safety glasses with side shields, proper gloves, and respiratory protection is required if airborne concentration exceeds TLV. At concentrations up to 5 PPM, a dust/mist respirator is recommended.	Threshold limit value (TLV) is 2.5 mg/m^3 with medical conditions generally recognized as being aggravated by exposure. To meet TLV requirements, use general or local exhaust ventilation. According to OSHA Table Z-1 Limits for Air Contaminants for synthetic graphite are 15 mg/m^3 *total dust* and 5 mg/m^3 *respirable fraction.*
Methanol	Methanol is a colorless liquid with a strong alcohol odor. It reacts violently with oxidants, mixes well with air and readily forms explosive mixtures.	Inhalation of methanol may cause cough, dizziness, headache and nausea. Methanol is readily absorbed through the skin and may cause irritation and pain.	Methanol is a CAA hazardous air pollutant (HAP), is a CERCLA hazardous substance, is regulated as TRI chemical and is regulated under OSHA. An OSHA PEL of 260 mg/m^3 has been established for methanol.

M30A1

The M30A1 gun propellant is a triple-base formulation that contains approximately 27.96% nitrocellulose (NC), 22.47% nitroglycerin (NG), 46.92% nitroguanidine (NQ), 1.5% ethyl centralite (EC) stabilizer, 1.0% potassium sulfate, and 0.15% graphite. Demilitarization uses humic acid and potassium hydroxide.

INGREDIENT	DESCRIPTION	ENVIRONMENT, SAFETY, AND HEALTH EFFECTS	REGULATION
Nitrocellulose (NC) (CAS# 09004-64-17-5)	Nitrocellulose is a white fibrous/cubed/granular solid. Sometimes called "gunpowder" or "guncotton", nitrocellulose is incompatible with strong oxidizing agents, strong acids, strong bases, and amines. It is more stable than black powder, and it produces a much greater volume of hot gas.	Nitrocellulose is extremely flammable and can be easily ignited by heat, sparks or flames. Workers should practice extreme care in handling nitrocellulose as it a chronic health hazard, and a moderate acute health and contact hazard. Inhalation or contact may irritate or burn skin and eyes; fire may produce irritating, corrosive and/or toxic gases; and vapors may cause dizziness or suffocation.. Conditions to avoid include heat, flame, other sources of ignition, light, and shock. Toxic gases produced upon decomposition may include nitrogen oxides, hydrogen cyanide, carbon monoxide, and carbon dioxide. Facilities should use adequate general or local exhaust ventilation to keep vapor and mist levels as low as possible. Approved respiratory protection is required if airborne concentrations are expected to exceed acceptable limits. Safety glasses with side shields and rubber gloves are recommended as eye/skin protection for workers. Proper storage of nitrocellulose consists of a cool, dry, well-ventilated, flammable liquid storage area in light-resistant containers.	
Nitroglycerin (NG) (CAS# 53-53-0)	NG is a colorless to pale yellow, clear, odorless, oily solution or crystalline solid. NG is highly soluble in water, and should be protected from freezing or extremely low temperatures, and excessive light or heat.	Overexposure to NG may cause headache, nausea, vomiting, apprehension or restlessness, muscle twitching, dizziness, metheglobenemia, and abdominal pain.	NG is regulated under RCRA, is a Superfund hazardous substance, is subject to TRI reporting requirements, and is a California Air Toxics Hot Spots chemical. An OSHA PEL of 2.0 mg/m^3 has been established for NG.
Nitroguanidine (NQ) (CAS# 556-88-7)	NQ is a white powder that is slightly soluble in water. It is incompatible with strong oxidizing agents and strong bases.	NQ may be harmful if absorbed through, if inhaled, or if swallowed. Dust and vapors can cause irritation to the respiratory tract. MSDS notes that the toxicological properties of NQ have not been fully investigated.	EPA has recently established a health advisory for NQ in drinking water.
Ethyl Centralite (CAS# 85-98-3)	Ethyl centralite is a white crystalline solid with a peppery odor used as a stabilizer for nitrocellulose-based smokeless powder and in rocket propellants. Ethyl centralite is not soluble in water and reacts violently when severely shocked or exposed to extreme	Ethyl centralite presents a slight health, contact, and fire hazard. Upon decomposition, toxic NOx gases are produced. When working with ethyl centralite personnel should always wear gloves, mask, goggles and use a hood. In instances of skin contact, it is recommended that the affected area be washed liberally with soap and water. A local exhaust system is required when used.	N/A

INGREDIENT	DESCRIPTION	ENVIRONMENT, SAFETY, AND HEALTH EFFECTS	REGULATION
	temperatures. Fire or excessive heat may cause production of hazardous decomposition products.		
Potassium Sulfate (CAS# 7778-80-5)	Potassium sulfate is an odorless white granular solid or powder that is soluble in water and incompatible with aluminum and magnesium	Upon decomposition, potassium sulfate may produce hazardous sulfur oxides and potassium oxides. When working with potassium sulfate, personnel should wear protective gloves, clean body-covering clothing, safety glasses, and a respirator when the exposure limit is exceeded.	Potassium sulfate has an OSHA PEL of 5 mg/m^3 (as respirable dust), and an ACGIH TLV of 0.15 mg/m^3.
Graphite (CAS# 07782-42-5)	Graphite is a dark gray to black odorless powder which is combustible and should be kept away from heat, sparks, and flame in a tightly closed container. Contact with air and moisture should be avoided in storage areas. Less than 0.1% is soluble in water, making it negligible.	Personal protective equipment for workers include safety glasses with side shields, proper gloves, and respiratory protection is required if airborne concentration exceeds TLV. At concentrations up to 5 PPM, a dust/mist respirator is recommended.	Threshold limit value (TLV) is 2.5 mg/m^3 with medical conditions generally recognized as being aggravated by exposure. To meet TLV requirements, use general or local exhaust ventilation. According to OSHA Table Z-1 Limits for Air Contaminants for synthetic graphite are 15 mg/m^3 *total dust* and 5 mg/m^3 *respirable fraction.*
Potassium Hydroxide (CAS# 1310-58-3)	Potassium hydroxide is a white solid with no odor. It is a strong base, reacts violently with acid, and is corrosive in moist air toward metals such as zinc, aluminum and tin.	The substance is corrosive to the skin, eyes, and will cause a burning sensation if inhaled or ingested. Local exhaust ventilation should be used when working with the product, and personal protective clothing, gloves, and eye protection are recommended.	Potassium hydroxide is regulated as a Superfund hazardous substance. An OSHA PEL has been established at 2 mg/m^3

Appendix B

Markets for Recovered RDX

Markets for Recovered RDX

Company/ Location	Point of Contact	Interest in Recovered RDX/HMX	Remarks
Owen Oil Tools, Inc. Fort Worth, TX	Ms. Lyn Davis 817/551-1146 Ext.190	Yes, specialize in manufacturing of explosives for the oil drilling industry	Prior to accepting the material, Owen Oil Tools, Inc. would request a copy of specifications, quantity, pricing, and samples for evaluation.
The Ensign-Brickford Company Simsbury, CT	Mark Stoffer 860/843-2359	Yes, manufacturer of explosives for the mining industry	Because of previous experiences with the use of demilitarized explosive material were less than favorable, as the material was not of military specifications standards, samples would need to be sent to their internal research lab for analysis of purity levels. After analysis, a decision would be made whether or not to include the recovered material in their production process.
Accurate Energetic Systems, LLC McEwen, TN	Bill Robinson and Russ Ashbrook 615/729-4207	Yes, manufacturer of explosives for the mining and oil industries	Accurate has been contacted by TPL, Inc., and expressed a need to know the cost and granular size of the potential incoming material. Apparently Accurate has encountered economic problems with the granular size of incoming RDX/HMX material. Often the raw material they receive requires recrystallization. Therefore the cost of the incoming material must be low enough to offset the cost of recrystallization. Their customers usually require the RDX material to meet Mil. Reg. 4544 with ~99.8% purity. Accurate's research staff would characterize the material and consider the incoming RDX/HMX material for different production purposes. Interest was also expressed in the possible use of recovered single and double based propellants (i.e., nitrocellulose). This material would also require analysis for the inclusion into the manufacture of small arm ammunition and other relative smokeless powder markets. Accurate openly expressed a desire to establish a progressive working relationship with DoD in the recovery of RDX/HMX material and sought specific information (quantity, granular size, cost) about the potential recovered material.
Sierra Chemical Company Sparks, NV	Tom Wright 702/358-0888	Yes, manufacturer of explosives for the mining industry	Sierra Chemical responded that they would use any and all recovered RDX/HMX offered for sale. The recovered material would be blended on-site to meet company specifications. They currently are purchasing RDX/HMX and Composition B from the Department of the Army.
Austin Powder Company Cleveland, Ohio	Bob Bellock and David True 614/596-5286	Yes, manufacturer of explosives for the mining and oil industries	Austin Powder Company are currently using demilitarized Composition B (TNT/RDX mixture) purchased from the Department of the Army, in their explosive production. Austin Powder Company has specification sheets that outline the production of various products (e.g. cast boosters). It was requested that recovered RDX/HMX material being marketed be accompanied with specifications, quantity, granular size, and cost for review and analysis prior to the procurement of these materials. Austin Powder Company expressed an interest to be place on future "mailing lists" of potential commercial buyers of reclaimed RDX/HMX material.

Company/ Location	Point of Contact	Interest in Recovered RDX/HMX	Remarks
Talley Defense Systems, Inc. Mesa, AZ	Greg Nolton 602/898-2299	Yes, for RDX only, manufacturer of solid propellants and pyrotechnics	Sample of RDX material would be requested along with specifications of the incoming material for possible inclusion in their production process.
Halliburton Energy Services, Alvarado, TX	Mike Peveto 817/783-5111	Yes, large manufacturer of explosives for the mining and oil industries	Internal research staff would analyze a sample of the RDX/HMX material for inclusion into their production of applicable explosive products based on the composition of the material.
St. Lawrence Explosives Corp. Adams Center, NY	Carl Lubbe 315/583-5432	No	St. Lawrence is a small manufacturer of explosives for the mining industry. They did not have an interest in the material but suggested other companies to contact; which are incorporated in the survey.
Slurry Explosives Corporation Oklahoma City, OK	Terry Wright 316/597-2552	No	Slurry Explosives manufactures "water gel" explosives for the mining industry, and was not interested in recovered RDX/HMX material.
Amos L. Dolby Company Corsica, PA	Scott Reinerd 814/379-3701	No	Amos L. Dolby expressed no interest in the use of recovered RDX/HMX. However, they did suggest other companies that were incorporated into the survey.
Washington Corporations Missoula, MT	Mike Ragbourn 406/523-1300	No	Washington is involved in underground coal mining and mining equipment leasing. As they are the "end user" of explosive material, they expressed no interest in recovered RDX/HMX. They suggested companies that were incorporated into the survey.
Goex, Inc. Moosic, PA	Mike Fahranger 318/382-9300	No	Goex is a small manufacturer of black powder for explosives and expressed no need for recovered RDX/HMX material.